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ADP022532

TITLE: U.S. Army Beam Power Tetrode Based Broadband Resonant
Coaxial Cavity High Power Amplifier System

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TITLE: 2006 IEEE International Vacuum Electronics Conference held
jointly with 2006 IEEE International Vacuum Electron Sources Held in
Monterey, California on April 25-27, 2006

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U.S. Army Beam Power Tetrode Based Broadband Resonant Coaxial Cavity High Power Amplifier System

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Abstract: This paper discusses a novel design for a 140MHz-1GHz broad-band resonant coaxial cavity high power amplifier system developed by Redstone Technical Test Center, ETM Electromatic, Inc. and BURLE Industries, Inc. Of particular interest are the three tunable cavities and the beam power tetrode that powers the high-power stage of the amplifier. Also discussed is the single broadband cavity used to tune the intermediate power stage of the amplifier.

Keywords: resonant coaxial cavity amplifier; beam-power tetrode; tunable cavity; high power; broad-band.

Introduction

Redstone Technical Test Center (RTTC) performs electromagnetic environmental effects testing for Army missile and Aviation systems to evaluate survivability and functionality when exposed to high level pulsed RF environments that may be encountered during the weapon system life-cycle. Especially challenging, is the development of high power tunable pulsed amplifier systems that are required to operate over a large frequency band of up to 2.8 octaves and at high output power (>200kW). In order to satisfy this requirement, RTTC in conjunction with ETM, Inc. and BURLE Industries, Inc. recently developed a beam power tetrode based system that could operate from 140-1000MHz and deliver approximately 250kW of peak power at a duty cycle of 2%. This paper details the technical qualities of the tetrode tubes developed and used in the amplifier system as well as the unique tunable cavities that allowed operation across the frequency range from 140-1000MHz.

System Overview

The amplifier system is composed of three major components (500W preamp, 10kW tetrode Intermediate

Amplifier – IPA, and 200kW tetrode High Power Amplifier – HPA) as shown in Figure 1. Of interest in this paper are the IPA and the HPA which employ three separate beam power tetrodes and resonant coaxial cavities to deliver 200kW of peak power from 140-1000MHz.

Y1411 IPA

The IPA provides the intermediate RF drive for the final high power stage of the amplifier system. The Y1411 IPA is a unique broadband resonant coaxial cavity amplifier that utilizes the BURLE 8791 tetrode and is tunable across the entire band from 140MHz-1000MHz (almost 3 octaves) while generating approximately 10kW of pulsed power. The cavity design is novel in that the mechanical circuit configuration remains fixed over this wide frequency range of nearly three octaves. Input tuning & matching and output tuning & loading occur within 50 Ohm surge impedance lines thus permitting the direct tap drive point and output connector to remain in fixed locations. Both direct tap points are formed with series L-C circuits designed to resonate at the geometric mean frequency of the band, and thus providing balanced impedance at the band edges.

The cavity operates in the $\frac{1}{4}$ -wave mode from 140 -350 MHz and in the $\frac{3}{4}$ -wave mode from 350 MHz to 1000 MHz. Quarter-wave traps are utilized in both the input and output circuits to eliminate shorting of the 50 Ω drive and 50 Ω load points. The traps are ganged together, reducing the trap control from two controls to one. Figure 2 illustrates the equivalent circuit for the IPA input/output resonant coaxial cavities.

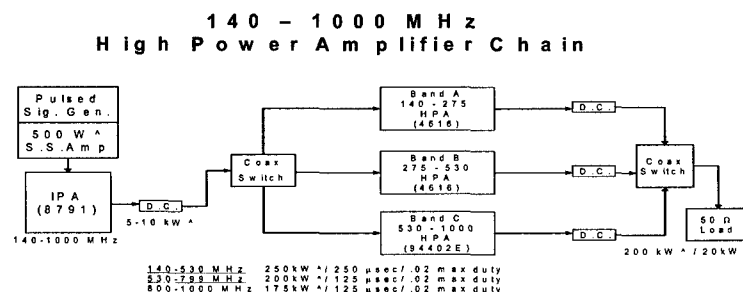


Figure 1. System Block Diagram

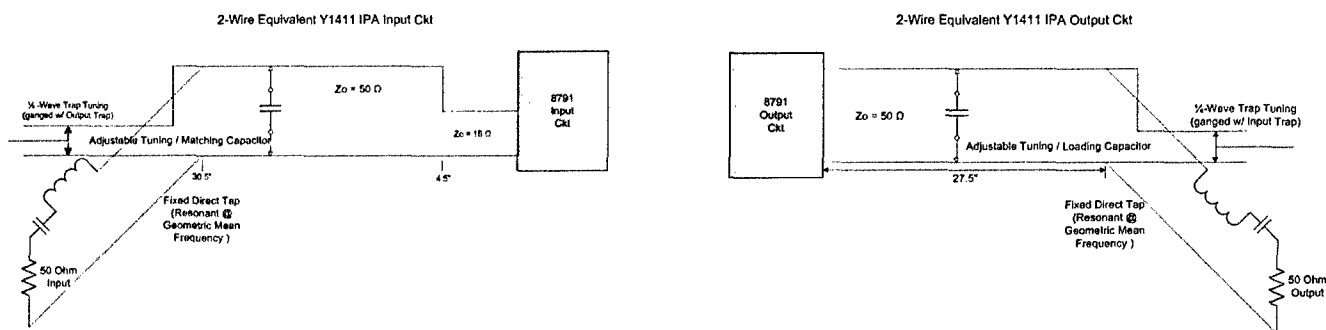


Figure 2. IPA Equivalent Input/Output Circuits

Burle 94402E Beam Power Tetrode

The final stage of the amplifier system is powered by the Burle 4616 and 94402E power tetrodes. The 94402E is a ceramic-metal, water-cooled super-power beam power tube intended for use as an RF-pulse amplifier at frequencies primarily between 600 and 1000 MHz. The tube was reengineered from the RCA A2606 (April 1960) for use in the high frequency portion of this amplifier and to support a similar Navy test program. The 94402E utilizes a matrix-oxide cathode which makes it efficient for pulsed applications and reduces the filament power requirements. Another special feature of the 94402E is a copper foil seal design that provides a low-inductance RF path thus making it more efficient at the high frequency portion of the amplifier (>500MHz).

Broadband Resonant Coaxial Cavity

The high power stage of the amplifier system utilizes three tunable input and output resonant coaxial cavities in order to match the tetrode input and output impedance

with the characteristic impedance of the transmission lines. The high frequency portion of the amplifier system employs the Y1414 which is a $\frac{3}{4}$ -wave coaxial resonant cavity that operates with the 94402E, High Power Tetrode and covers a frequency band of 530 MHz – 1000 MHz. The Y1414 output cavity has an adjustable tuning short to tune the cavity and a capacitive loading probe to couple the RF energy out of the cavity. The Y1414 input circuit, which also operates in the $\frac{3}{4}$ -wave mode, is unique in its construction having a telescoping Low- Z_0 section that adjust from 1.65" in the fully collapsed position to 4" in length at its fully extended position. Three fixed operating positions are required to cover the 530 MHz to 1000 MHz band; 3.15" (530 – 680 MHz), 2.2" (680 – 800 MHz), and .8" (800 – 1000 MHz). Tuning and matching of the input circuit are accomplished by a tuning short and coupling capacitor. An example of the 94402E input tuning curve is shown below in Figure 3.

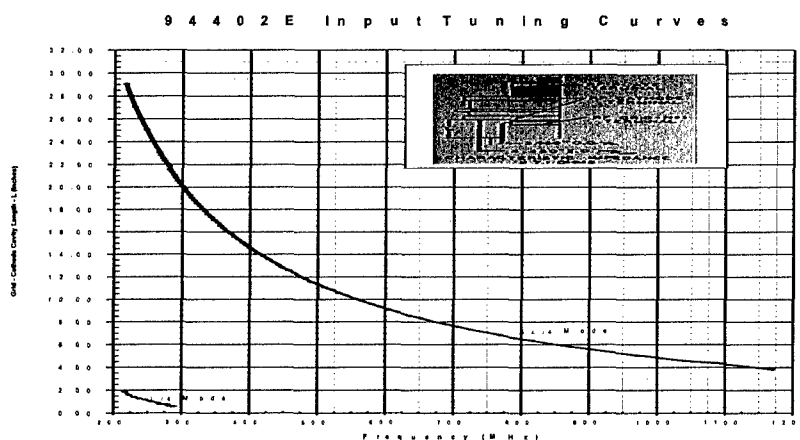


Figure 3. 94402E Input Tuning Curves